Building Maintenance Prioritization Using Programming Model

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Abstract*: *Buildings are the assets constructed to serve the activities of the users. Naturally along with its life cycle buildings are bound to deteriorate. In order to have a sustainable performance of the building, proper maintenance is to be carried out. Condition-based maintenance is considered as an effective approach over time-based maintenance because of its ability in minimization of total maintenance cost. The absence of building maintenance decision-making tool and the limited budget allocation are some of the factors causing the unmanaged maintenance activities. However, it is nearly not possible to manually monitor a large number of buildings and to make decisions, without a supporting decision-making tool. The study aims to develop a programming model for building maintenance prioritization. Java program is developed to execute the model. The condition of the building and rate of deterioration are considered as basic parameters in developing the model. There are three strategies for maintenance provided, Light repair, Rehabilitation and Renovation, having a different level of impact on the condition level of the building. A case study is conducted to implement the model involving 5 buildings having different condition level over a plan period of 10 years. The result suggests the year of maintenance and a cost-effective strategy for each building. It supports the decision makers in forecasting the budget requirement for each year and enables effective decision making. It supports in having an overall minimization of cost of maintenance because the strategy is applied as soon as the building reaches its minimum acceptable limit.

Index Terms*: *Building maintenance, Condition-based maintenance, Decision-making tool, condition-index.

I. INTRODUCTION

The building is the most important asset for any organization. Mainly for the universities, the built facilities are primly essential for the smooth administration and development [6], [2]. Buildings are the one involving a significant amount of resources and investment [1]. In many countries, studies show that 50 per cent of the total turnover is of the construction industry [1]. Every building is constructed to serve the activities of the users. Buildings, during construction, are designed to have a particular service life. That will not change the fact that buildings will deteriorate along with its life cycle.

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In order to satisfy the designed objective and to provide optimal service for the users, the building should be in good condition [4]. To achieve this, building maintenance management should be given priority. Maintenance term has been defined and redefined by different authors and is believed that it has been evolved over time [7]. From being a fundamental technical skill, maintenance management has reached to be a multi-functional process. The value of the building highly depends upon the quality of maintenance invested in them. Maintenance management supports in obtaining maximum benefit from the investment made on the maintenance activities. Maintenance of buildings is ultimately defined as the process that is intended to retain or restore the asset to a state in which it can perform its designed function. Different types of maintenance management approaches have been evolved, mainly time- based maintenance and condition based maintenance [5], [8]. In India, maintenance management is not provided with much importance as like construction of the buildings. Many researchers have been contributed to the development of different models for the construction process [3]. There is very less work contributed to the development of models for the maintenance process of the buildings. As the maintenance management involves a huge investment, we need to have a model that suggest and support the decision makers to wisely make decisions on the maintenance activities. It is also equally important to identify when and where to implement the maintenance other than how much we invest in them. Condition based maintenance helps in having maintenance that will keep the building in its acceptable level throughout the period rather than time-based maintenance [5]. The maintenance need can be identified easily if there are less number of buildings in the organization. When the number of buildings is reasonably greater, like university buildings, identification of which building need to be maintained and associated decision making becomes more complicated. The paper aims to develop a building maintenance prioritization model that will help to overcome this problem.

II. THEOREITICAL MODEL

The objective of the study is to develop a decision-making tool that supports the selection of building for the maintenance and the strategy to be applied for the maintenance activity. In order to prioritize the buildings for the maintenance, the condition of the building is selected as the parameter in the model. The theoretical condition index is taken in order to simplify the calculation in the model [9].

The model has five levels of building condition as very good, good, average, poor and bad.

It will classify the building into its condition level based on the index value. The highest point in building condition is 95 and lower is 35. The acceptable level of condition for the building is good which is indexed to 75.

Fig. 1 The building condition level over the life cycle

Fig. 1 shows that the building through its life cycle will degrade its condition and reaches the salvage state at the end of the useful life. When it reaches the acceptable limit which is here 75 and below, maintenance need to be initiated to regain its condition and by this, one can maintain the functionality and value of building. When the building deteriorates less the acceptable limit, the model suggests the year and the cost-effective strategy for the maintenance. The rate of deterioration is considered according to the location of the study as 2% every year. Three types of maintenance strategy are considered for upgrading the building to an acceptable condition proposed in the model. They are Light repair, Rehabilitation and Renovation. The relation between the strategies and upgrading condition level of the building is shown in the fig. below.

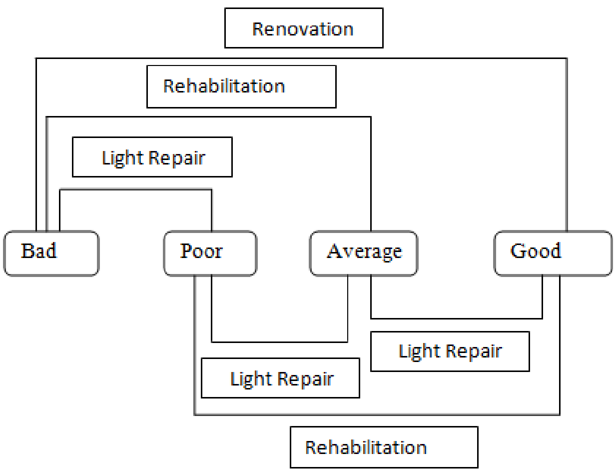

Fig. 2 Building Condition level and Building maintenance strategies.

From Fig. 2 the strategy selected to improve the condition of the building is clearly represented. If the building is in bad condition, by implementing renovation, it reaches the good condition level whereas implementing rehabilitation makes the building average condition and Light repair makes it to poor condition. The similar pattern is followed for the poor and average initial building condition.

III. MODEL FORMULATION

The model objective is to find suggest the cost-effective strategy to be applied to which building in which year. The variables, parameters and the objective function of the model are presented as follows.

$$\text{Min } \sum_{n=1}^{n} \sum_{y=1}^{y} \sum_{k=1}^{k} C_{nk} S_{nyk} \qquad (1)$$

$$\sum_{n=1}^{n} \sum_{k=1}^{k} C_{nk} S_{nyk} \le B_y \qquad (2)$$

$$\sum_{k=1}^{k} S_{nyk} * I_k + CB_{ny} = CA_{ny} \qquad (3)$$

$$CB_{ny} = CI_n \qquad (4)$$

$$CB_{n\,y+1} = CA_{ny} *\left(\frac{100-Dp}{100}\right) \qquad (5)$$

Where n – Number of buildings
y – Number of years (plan period)
k – Number of strategy (k= {1,2,3})
C- Cost of each strategy ($C_1 > C_2 > C_3$)
C_1, C_2, C_3 are the cost of strategy 1,2,3 respectively
S – Strategy to be implemented
B – Budget allocated in the y^{th} year
CB – Condition of the building before strategy application
CI – Condition index of the building in the first year
I – Improved condition of building after the implementation of the strategy
CA – Condition of the building after strategy application
Dp – Degradation rate of the buildings each year

Equation (1) is the objective function of the model which enables the selection of cost-effective strategy for each building in particular year when it is below the acceptable limit and helps in minimization of overall cost of maintenance. C represents the Cost of strategy and S represents the strategy to be applied when building is below the acceptable condition level.

Equation (2) is constraint that the cost of maintenance annually should not cross the budget of the year. B is the budget allocated for each year. It may be included in the model or it can be predicted from the model. In the equations n is the number of buildings, y is the number of years the prioritization is going to be predicted and k represents the different strategies used in the model with numbers 1,2,3.

Equation (3) shows that the condition level of building after implementation of strategy is the sum of condition before strategy application and the improved condition of the building. I represent the improved condition level when the strategy is applied for the building. CB is the condition of the building before the strategy implementation or at the time of assessment. It is also called as initial condition index of the building.

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Equation (4) is the initial condition of building which is the damage possessed by the building at the time of assessment later taken as the input for model implementation. Equation (5) states the condition of the building in the first year multiplied by the degradation percentage gives the condition of building for next year. The degradation rate of building may be different for different locations and type of buildings. CA is the condition of the building after the implementation of the strategy.

The above represented equations are included in the programming model developed using java. The java program is developed to execute the model. The programming model developed is user-friendly which allows the users to use the same model with a different set of data. The additional constraints and parameters can be easily added to the programming model. The programming model is presented below.

Algorithm:

Input: 1. Number of buildings
2. Degrade Percentage
3. Strategy name, cost, condition level, index-change
4. Number of years
5. Building name and condition index

Output: 1.Table showing each building condition index and corresponding condition level
2. Table showing the year of maintenance and maintenance strategy

1. Create strategy structure with name, cost, condition level, index change.
2. Create building structure with name, condition index, condition level.
3. Get the input for total number of buildings and degrade percent.
4. Create array of strategy structure as per required.
5. Get the details of strategy as input and store in array.
6. Create array of building structure.
7. Get the condition index of each building as input and store in array.
8. For each building loop
    8.1 Set the condition level of building based on given condition index
9. End For
10. For each year loop
    10.1 For each building
        10.1.1 If (Condition level of building)
            10.1.1.1 Strategy is applied and upgrade level and condition index of building
        10.1.2 Else
            10.1.2.1 Degrade the condition index based on given input as degrade percent
        10.1.3 End If
        10.1.4 Update the building condition index and condition level
    10.2 End For
11. End For
12. End

IV. CASE STUDY AND RESULTS

The buildings which are selected to implement the model have different condition level and have three options for maintenance strategy. The created model will aim in finding a cost-effective strategy for the building to be in the acceptable condition level and the year of application of maintenance throughout the plan period. The condition index is obtained by using the theoretical condition model with the basic set of data like age, type of buildings and the standard estimated useful life of each component, modified after (Eric Teicholz) work to simplify the calculation process in the model [9].

Table I Building Initial Condition

Building	Condition Index	Condition Level
A	42	Bad
B	70	Average
C	57	Poor
D	80	Good
E	87	Very Good

Table I shows the initial condition level of the buildings based on the condition index. The condition index values is given as the input and the model classify the building condition into Very good, Good, Average, Poor and Bad based on the condition index value. The limits for the classification can be modified while using different set of data if required.

Table II Results derived from the model

Building	Year of Maintenance	Maintenance Strategy
A	1 6	Renovation Light Repair
B	1 6	Light Repair Light Repair
C	1 6	Rehabilitation Light Repair
D	5 10	Light Repair Light Repair
E	9	Light Repair

The result of the model is presented in Table II. It shows the year in which the building requires maintenance and the chosen strategy of maintenance. Building A, Building B and Building C are to be maintained in the first year as they are below the acceptable condition level. Building D requires maintenance in the fifth year. Subsequently, all most all buildings need to be maintained second time (except Building E) as they will deteriorate along with the time and reaches below the acceptable level. Attending the maintenance requirement as soon as it reaches the acceptable level helps in minimization of overall cost of maintenance and enables effective functioning of the buildings.

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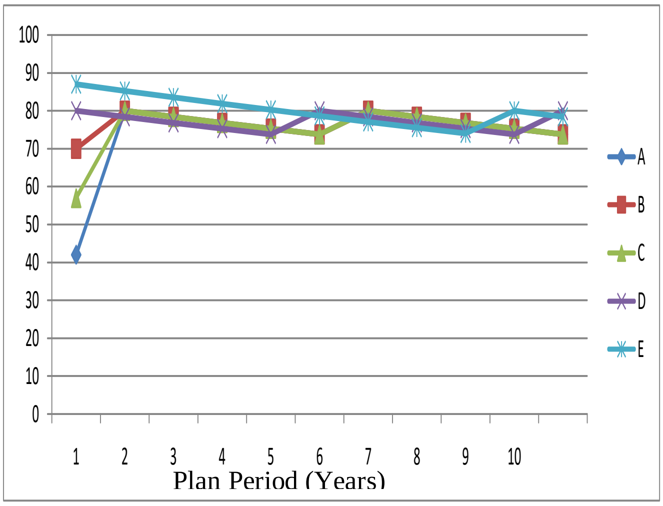

Fig. 3 Graph representing the building condition performance.

The graph has the plan period in X-axis and the condition index of the building in Y-axis. The graph shows the change of condition index of the buildings over the plan period. When the condition of the building deteriorates below 75, the acceptable condition level, maintenance is suggested and upgraded the condition index of the building.

V. CONCLUSION

The study employs the programming model for the prioritization of building maintenance for a particular plan period. The building condition level and the rate of deterioration are considered for selecting the year and strategy of maintenance. The implementation of the proposed model is studied by considering five buildings having different condition level for a plan period of 10 years. The result from the model suggests the cost-effective strategy and the year of application of the strategy. Proper maintenance of the buildings will ensure sustainability in the performance of building through serving its desired function. The results from the model support the decision makers to have a prior prediction of which building to be maintained with which strategy of maintenance. It helps the owners to forecast about the needed budget for the maintenance activity in each year and to minimize the overall cost of maintenance. It also supports in an effective decision making for the allocation of resources like manpower and materials based on the strategy suggested and scheduling of maintenance activities. The specified model is user-friendly and the same can be used with different set of data. It helps in minimization of overall cost of maintenance as the building is treated as soon as it reaches the minimum acceptable condition. Results have to be cautiously treated. Future scope calls for the addition of some more strategies and criteria to generate better results.

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